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Human performance and biorhythms

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HUMAN PERFORMANCE AND BIORHYTHMS

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THESIS

HUMAN PERFORMANCE AND BIORHYTHMS

by

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September 1975

Thesis Advisor: D.E. Neil

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Abstract (continued)

for the third cycle and human performance. Further analysis using the χ^2 one sample test showed no significance between critical days and categories of performance at the .05 level.

Human Performance and Biorhythms

by

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ABSTRACT

Using a serial memory task, human performance and biorhythms were studied in the laboratory for a fifteen week period. The purpose of the experiment was to determine whether dependency between human performance and biorhythmic cycles existed for the subjects observed. Analysis of the data using the Chi-Square Contingency Test collected from 4 subjects showed a significant dependency at the .05 level existed between 2 of 3 biorhythmic cycles and human performance as well as near significant dependency existing for the third cycle and human performance. Further analysis using the χ^2 one sample test showed no significance between critical days and categories of performance at the .05 level.

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I. INTRODUCTION

A. BACKGROUND

In recent years, renewed scientific interest has been shown regarding the theory of Biorhythms. The original theory postulates that all human beings have three inherent "life cycle" rhythms: a 23 day physical rhythm, a 28 day emotional or sensitivity rhythm and a 33 day mental rhythm.

The details of the theory were first developed at the end of the 19th century by Dr. Herman Swoboda, a Swiss psychologist, and Dr. Wilhelm Fliess of Germany [Thommen, 1973]. Working independently, the doctors observed cyclic emotional and physical behavior in their subjects over a period of years. Their findings were published widely in Europe, however only brief scientific interest was evident.

The last biorhythm to be defined was the 33 day mental (or intellectual) rhythm, discovered in the 1920's by Dr. Alfred Teltscher, an Austrian engineer. He monitored the school achievement records of a large number of high school and college students for several years. His observation of varying school performance amongst the students led to the postulation of the 33 day mental rhythm. In later years, American researchers provided additional suggestive evidence of the existence of the 33 day rhythm by observing the performance of workers in railroad shops over periods of many months [Thommen, 1973].

The theory suggests that each biorhythm is characterized by two parts of a cycle. During the first part or "up" cycle an individual's potential for above average performance is enhanced. Conversely, the second (or "down") portion of the cycle represents an individual's potential for below average performance. The point at which the biorythm crosses the

horizontal axis is referred to as a critical day. Biorhythmic theory postulates that a critical day can be marked by extraordinary good or bad performance. Consequently, the potential for a particular type of performance is subject to question on a critical day. Evidence exists to show both good and bad performance on critical days as shown later in the thesis. A graphical representation of the theory of Biorhythms appears in Figure 1.

Each biorhythm is characterized by certain types of characteristics. Thommen [1973] suggests that subcategories are contained in each cycle. The subcategories are specified in Table 1.

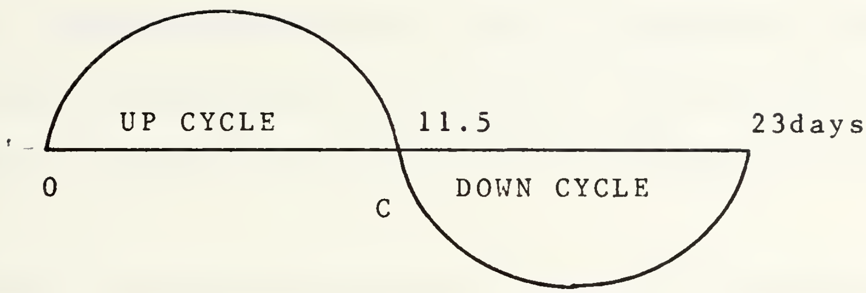
Table 1

Subcategories of Each Biorhythmic Cycle

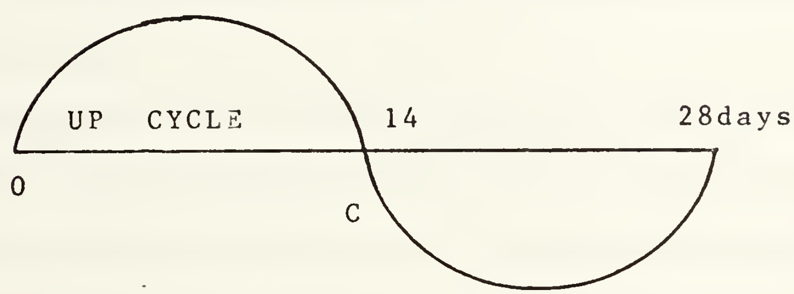
PHYSICAL CYCLE	EMOTIONAL (Sensitivity)	MENTAL (Intellectual)
physical strength	sensibility	intelligence
endurance	nerves	memory
energy	feelings	mental alertness
resistance	intuition	logic
confidence	cheerfulness	reasoning power
	moodiness	reaction
	creative ability	agility
		ambition

Since 1950 an increasing number of industrial concerns worldwide have begun to investigate biorhythms and the effect of the hypothesized cyclic behavior on worker performance. The experience of most concerns is that there appears to be a significant relationship between biorhythms and worker performance in the form of industrial accidents. A respected Industrial Hygienist, R.K. Anderson, has carried out extensive biorhythmic

PHYSICAL BIORHYTHM



SENSITIVITY BIORHYTHM



INTELLECTUAL BIORHYTHM

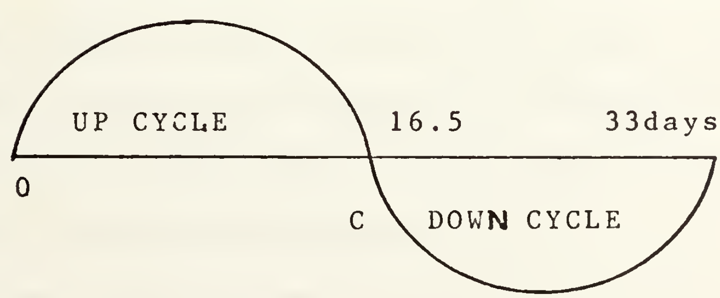


FIGURE 1

research in this country and abroad [Anderson, 1973]. In a review of his research efforts, Anderson presented results of a two year study of 1000 accidents. Analysis showed that over 90% of the accidents occurred on critical days of the hypothesized biorhythmic cycles [Anderson, 1973]. The subject of biorhythmic criticality will be addressed in a later section.

The study of cyclic human behavior is certainly widespread, especially in the area of circadian rhythms. Other more exotic studies include the work of Dr. Arnold Lieber of the University of Miami, who provided evidence of a cyclic murder rate coincidental with the rise of the full moon. His research was based on the study of 1800 murders in Dade County, Florida [Hackler, 1969].

Specific biorhythm studies have been published in the scientific literature. Wallenstein and Roberts [1973] used specific college football games and certain historical events, such as Custer's Last Stand, to examine biorhythmic validity. Willis [1972] analyzed data from hospitals, athletic events and single vehicle automobile accidents. Within his study he discussed several foreign cases of the application of biorhythms. One of the more successful uses of biorhythmic theory seems to lie with the Ohmi Railway Company of Japan. Since the inception of biorhythms in driver management the company has claimed over 2,000,000 kilometers of accident-free driving. These results are attributed to the employment of biorhythm theory in their safety program.

Perhaps the most publicized use of biorhythms has occurred in the study of aircraft accidents. United Airlines has been monitoring the biorhythms of over 28,000 ground workers for the past few years [Zito, 1975]. Although their work is in the developmental stage, the company

seems to be committed to further research. Other examples include the charting of United Airlines ground crews at National Airport in Washington, D.C. Supervisors advise workers when critical days will occur and the work is scheduled accordingly. Since 1973 accidents within United supervision at National Airport have been cut to one-half the former number [Zito, 1975].

Thommen [1973] cites several specific aircraft accidents and points out that they occurred on the critical days of the pilots. Analysis of this type may be open to question of scientific validity.

Organizations within the Department of Defense have undertaken research in the area of biorhythms. Research at the Naval Postgraduate School has included a study of 4000 aircraft accidents to determine if criticality of pilot's biorhythmic cycles was a factor [Sacher, 1974]. The results indicated that criticality was not a significant factor. Sink [1974] used a 70 day experimental task to show the biorhythmic periods in laboratory performance of selected subjects. The task required the subjects to depress a series of buttons when confronted with a display of random digits. Fourier analysis was performed on the performance data of the subjects. The results indicated that the postulated basic biorhythmic cycles exist. Giannotti [1974] studied various accident and academic data and showed significant relationships between the occurrence of industrial accidents and hypothesized biorhythmic cycles. Similar significance was shown for the relationship between academic performance and hypothesized biorhythmic cycles. He further developed a statistical technique that could be used to analyze accident and other human performance data.

Current work being done by the Department of Defense includes a study being conducted at Walter Reed Army Institute of Research. This study centers on biorhythms and drug abuse. Time series analysis techniques are applied to the data that is collected by use of sophisticated electronic monitoring equipment [Hegge, 1973]. Continuous recordings of electro-encephalograms, electroculograms, electrocardiograms, rheopneumograms and electrogastrograms combined with blood samples and behavioral observations were obtained. The United States Air Force School of Aerospace Medicine is conducting research on the interaction of biorhythms with Air Force operational requirements [Storm, 1973].

The general thrust of current research seems to be towards measuring the effects of cyclic behavior in humans with an eye towards the improvement of work scheduling to reduce possible contributory causes of accidents.

The idea of cyclic human performance brings to mind questions of possible measures that might be employed to characterize performance. Traditionally, long term "skill learning" performance can be thought to occur in three phases. The first phase is an early or cognitive phase in which the learning of the task to be performed takes place. The second phase is an intermediate or associative phase, characterized by rehearsal or practice of the task. The final phase is an autonomous phase in which there is less and less dependence on cognitive processes [Fitts and Posner, 1967].

According to the theory of Biorhythms it can be hypothesized that individual human performance should fluctuate sinusoidally [Thommen, 1973]. However, according to the skilled operator performance literature it would be possible to hypothesize that if task and testing requirements remain constant over a period of time, individual performance should

approach an asymptotic level and remain constant with the exception of slight fluctuations and pertubations [Fitts and Posner, 1967; Welford, 1968; Deese and Hulse, 1968]. Under the latter hypothesis the conclusion can be reached that individual performance data would not oscillate sinusoidally. Thus, the two theoretical approaches are contrasting in nature.

The idea of sinusoidal human performance provides a natural base for study in the present thesis.

B. PURPOSE OF THE EXPERIMENT

Although much work has been done in the field of biorhythms, few studies (with the exception of Sink, 1974) have addressed human performance as related to biorhythms in a controlled laboratory situation. Previous studies of biorhythms have been concerned with past events, usually some kind of accidents assumed to be caused by human error [Thommen, 1973]. Several questions arise with analysis of this type. For example, to say that an aircraft accident of a certain type occurred because the pilot was on a "down" day or a critical day (recall that the two are not the same) may be popular in some circles. However, the significance of criticality with relation to aircraft accidents would only be valid if a large sample of aircraft accidents were analyzed. Claims of certain accidents occurring on critical days of the individuals involved have appeared in the literature [Thommen, 1973; Zito, 1975]. However, the statistical validity of these claims can be questioned because the sample from which the accidents were taken is usually not defined or explained.

The same analogy used for aircraft accidents can be applied to human performance in general. The practice of identifying particular past

examples of good or bad performances in order to support biorhythmic theory is fraught with difficulties of scientific control.

The present experiment was undertaken in an attempt to provide additional information on the phenomena of biorhythms in a controlled laboratory situation. The use of such experimentation should provide the basis for statements of the validity of the concept and enable future work to concentrate on the applications of the theory to military and industrial problems in human performance.

Concrete results are being published wherever biorhythms are applied in work scheduling. There is good reason to support future research in this area within the Department of Defense.

The basic hypothesis of the experiment was that there is a dependency (statistical, not necessarily causal dependency) between biorhythmic cycles and human performance. A secondary objective of the experiment was to investigate whether or not the individual human performance observed was sinusoidal in nature.

II. METHOD

A. DESIGN

Data from the experiment was analyzed using nonparametric statistics in addition to standard statistical procedures.

The measure of performance was the ratio of the number of correct responses to the number of total responses to the stimuli given. Each subject acted as his own control. The important variable was human performance measured daily over a 15 week period.

The 15 week period was chosen because it represented each biorhythm going through at least 3 complete cycles. Thus, although the subjects had varying degrees of success in the experiment, their measures of performance were related only to their individual correct responses.

B. SUBJECTS

Four male subjects were chosen on the basis of their familiarity with the apparatus to be used for the experiment. The subjects were student officers of the Operations Research Curriculum at the Naval Postgraduate School. The subjects ranged in age from 30 to 34 years. The subjects were told that the experiment concerned the measure of human performance over a long period of time. They were further told that their biorhythmic cycles would be charted. This was not done until after the conclusion of the experiment. The subjects were not aware of their biorhythms (up or down) during the course of the experiment.

C. STIMULI AND APPARATUS

The apparatus used was the Miniaturized Response Analysis Tester (RATER) built by General Dynamics Corporation. The RATER is a psychomotor

testing device designed to provide reliable measurement of any impairment of response speed and short-term memory for either patterned or colored stimuli.

The RATER system is divided into two parts. The control unit provides random stimuli to the display unit in the form of 4 different colors or 4 different symbols. The colors used are blue, red, yellow, and green. There are various random patterns that may be selected at the control unit as well as various speeds of stimuli presentation. The stimuli for the RATER are presented on a small screen. A schematic diagram of the system is shown in Figure 2.

The subjects were seated inside a soundproof chamber which contained the RATER screen. Four response buttoms were provided coinciding with the 4 colors so that the subjects could respond in the correct manner. Three modes of color presentation were used during each daily experiment. The modes were self-paced in nature. In the Delay One mode, the RATER selected colors for presentation at random. The first color appeared for 1½ seconds, disappeared and was followed by the second color for 1½ seconds. The second color remained until the subject responded correctly and a new color appeared. The correct response in the Delay One mode would be to press down the button corresponding to the color previously shown before the present color, hence the previous color "one back." All correct responses as well as total responses were recorded on the RATER control unit. All delay modes lasted 2 minutes.

In the Delay Two mode three colors were presented for 1½ seconds each. After the third color was presented the subject was required to respond to the first color presented and so on until the 2 minute sequence was completed.

RATER CONTROL UNIT

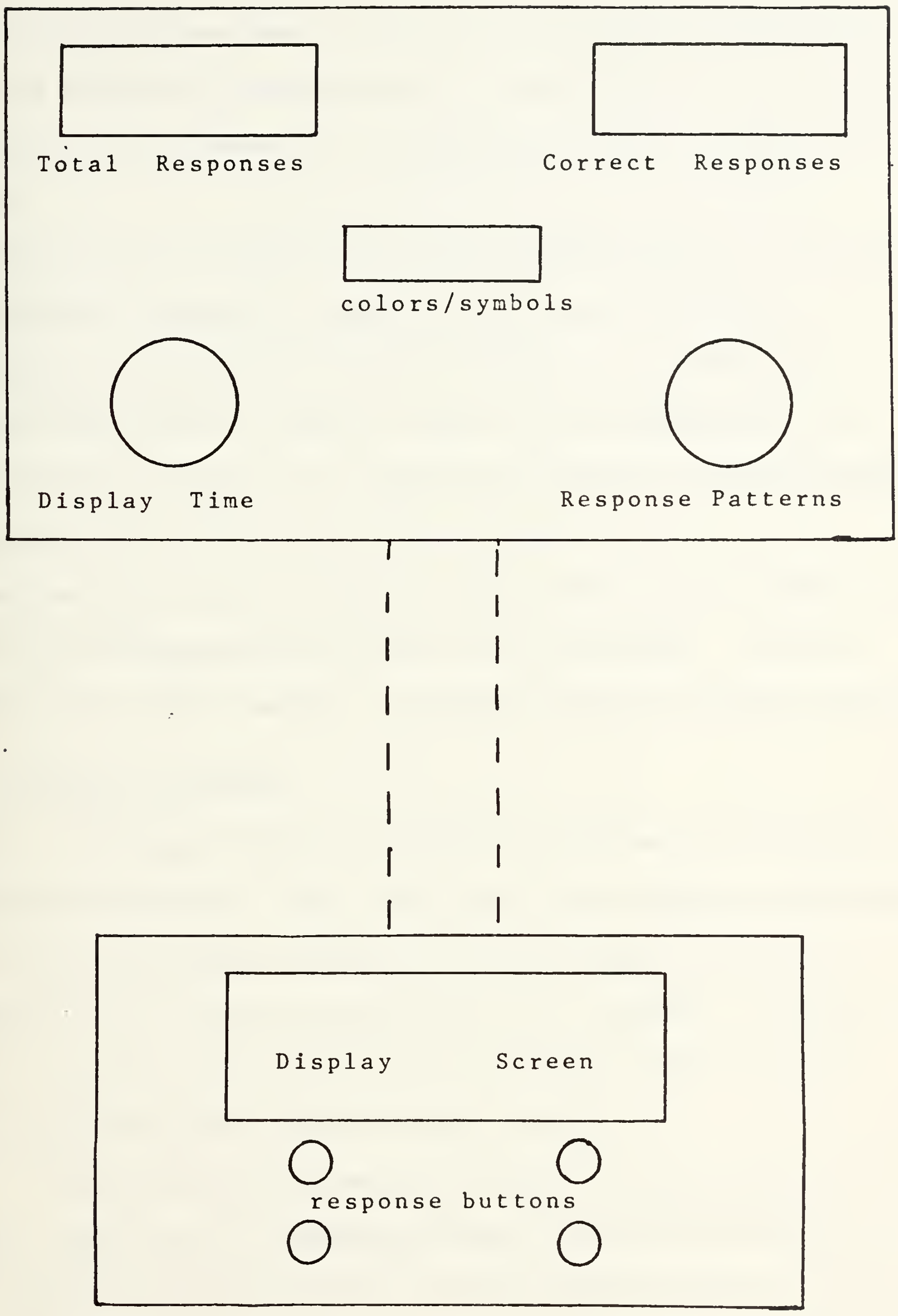


Figure 2. RATER Schematic

In the Delay Three mode four colors were presented for 1½ seconds each. After the fourth color was presented the subject was required to respond to the first color presented. The sequence of colors continued for 2 minutes.

The data was collected over a period of fifteen weeks. All subjects were tested at a minimum of twice per week during the time span. The experiment was conducted at the same time each day. However, while external events were not under the control of the experimentor, the subjects did not encounter any significant emotional or severe physical occurrences during the course of the experiment.

As previously noted, the subjects were familiar with the RATER, having used it in previous work not related to this experiment. The usual learning curve effect was thus not observed during the present experiment.

D. STATISTICAL PROCEDURES

1. The primary statistical technique chosen was the Chi-Square Continency Test [Siegel, 1956]. The test is well suited for behavioral work and the nonparametric nature of the test does not require the assumptions as to population distribution, etc. needed for parametric tests. The basic theory underlying the Chi-Square Contingency Test can be found in Larson [1969] and Siegel [1956].

The Chi-Square Test was used to test the basic hypothesis of the thesis: that there is a dependency between the human performance of a task and each biorhythmic cycle. As stated before, biorhythm theory holds that an individual's capacity for excelling in a task is greater during the first half of the cycle. He will experience a reduction in capacity during the second part of the cycle.

Data from the experiment was arranged according to the following tableau: [Larson, 1969]

Table II

Experimental Data Tableau

LEVEL OF CLASSIFICATION 2

LEVEL OF CLASSIFICATION 1

	1	2	3	4	5	....	C	
1								$P_{1\cdot}$
2								$\cdot$
3								$\cdot$
4								$\cdot$
$\vdots$								$\vdots$
r							cap $\rightarrow X_{rc}$	$P_{r\cdot}$
							$P_{\cdot c}$	

Following Giannotti [1974]:

a) Assume n observations. Each observation can be classified according to two different classifications. One classification has C levels with $C \geq 2$ and the other has r levels with $r \geq 2$.

b) $$\sum_{j=1}^{C} \sum_{i=1}^{r} X_{ij} = n$$

c) $$\sum_{j=1}^{C} \sum_{i=1}^{r} P_{ij} = 1$$

d) $nP_{ij} \geq 5$

e) Let x_{ij} be the number of observations which fall into class i classification one and class j classification two.

f) Let P_{ij} be the probability that an observation falls into class i classification one and class j classification two.

g) $\dot{P}_{i}\cdot = \frac{x_{i}\cdot}{n}$ where $x_{i}\cdot = \sum_{j=1}^{C} x_{ij}$

h) $\dot{P}\cdot j = \frac{x\cdot j}{n}$ where $x\cdot j = \sum_{i=1}^{r} x_{ij}$

i) Therefore:

$H_o : P_{ij} = (P_{i}\cdot)(P\cdot_{j})$ for all i and j

$H_1 : P_{ij} \neq (P_{i}\cdot)(P\cdot_{j})$

j) If H_o is time:

$$V = \sum_{j=1}^{C} \sum_{i=1}^{r} \frac{(x_{ij} - n\dot{P}_{i}\cdot\ \dot{P}\cdot_{j})^2}{n\dot{P}_{i}\cdot\ \dot{P}\cdot j} = \chi^2\ (r-1)(C-1)^{(1-\alpha)}$$

k) Reject H_o if:

$V > \chi^2(r-1)(C-1)^{(1-\alpha)}$

2. The above tableau was applied to the data from the experiment in Table III:

Table III
Two Way χ^2 Contingency Table

CLASSIFICATION 2

CLASSIFICATION 1	observed good performance days	observed bad performance days	
	x_{11}	x_{12}	1st ½ cycle
	x_{21}	x_{22}	2nd ½ cycle

For example x_{11} represents the number of observed good performance days on which the individual's performance was above average and which occurred during the first half ("up") cycle. The preceeding format was employed during the first analysis in the RESULTS section.

3. The above format was altered in the second analysis of the RESULTS section.

(a) X = performance score of the task for a given day.

(b) $\bar{X}$ = average or mean score of an individual subject over the course of the experiment.

(c) S = sample standard deviation of the performance scores of an individual subject over a given period.

The above statistics were used to determine S so that additional categories of classification 1 could be employed in the second analysis of results.

4. The biorhythm cycles are commonly portrayed in sinusiodal form. Some question exists as to whether performance can be correlated with the sinusoidal form of each biorhythmic cycle. Regression analysis was employed to determine whether or not the human performance for the present experiment could be correlated with sinusoidal periodicity. The following equations were applied: [Huntsberger, 1967]

(a) $Y = a + bX$ where $X = \dfrac{\sin 2\pi d}{\text{period}}$

d = day of cycle

Y = performance score.

(b) $$S^2Y \cdot_X = \frac{1}{n-2}\,[\Sigma Y^2 - b\Sigma XY]$$

(c) $$S_b{}^2 = \frac{S^2Y \cdot_X}{\Sigma X^2}$$

(d) $S_b = \sqrt{S_b^{\,2}}$

(e) $$\left.\begin{aligned} \Sigma Y &= aN + b\Sigma X \\ \Sigma XY &= a\Sigma X + b\Sigma X^2 \end{aligned}\right]$$ solving simultaneously yields a and b

III. RESULTS

A. The primary objective involved the consideration of each biorhythm separately for each subject, pooling the daily performance scores of the subjects and formulating overall results. The measure of performance was:

$$X = \frac{\text{total correct responses}}{\text{total responses}} = \text{daily performance score}$$

The variable X was a function of the three delay modes, and one overall X for a particular day was computed. In addition $\bar{X}$ and S were determined for each subject. Table IV summarizes the data:

Table IV

Characteristics of Daily Performance Scores

SUBJECT	DATA COLLECTION SAMPLE	$\bar{X}$	S	S/2
#1	31	.671	.041	.0205
#2	32	.708	.043	.0215
#3	34	.812	.040	.020
#4	33	.786	.030	.015

The daily performance score data was then considered in light of each subject's charted biorhythmic cycles, obtained by use of an IBM 360 FORTRAN program [Shudde, 1973]. All performance days in which criticality was noted within a particular biorhythm were not considered until the third stage of the analysis. For example, if subject 1 performed the task on May 1st and his physical biorhythm chart indicated a critical day, that data point was separated out for later analysis because of the unpredictability of performance on critical days postulated by the theory.

Thus, only those days in which a definable up or down cycle occurred in a particular biorhythm were considered in the first and second parts of the analysis. The data was compared day by day for each subject relative to his biorhythms and performance score for that day. The information thus gained for all subjects was then pooled together for analysis.

B. FIRST ANALYSIS RESULTS

H_o: human performance observed is independent of biorhythmic cycle

H_1: dependency exists between human performance observed and biorhythmic cycle

$\alpha = .05$ using $\chi^2_{(1)}$ statistics

good performance = scores at or above average

bad performance = scores below average.

1. Physical Biorhythm

Table V

χ^2 Contingency Table for Performance Scores Versus Physical Biorhythm

BIORHYTHMIC CYCLE	PERFORMANCE: good	PERFORMANCE: bad	
1st ½ up cycle	29	24	
2nd ½ down cycle	28	33	
			114

V = .882, do not reject H_o since $\chi^2_{(1).95} = 3.84$

2. Sensitivity (Emotional) Biorhythm

Table VI

χ^2 Contingency Table for Performance Scores Versus Sensitivity Biorhythm

BIORHYTHMIC CYCLE	PERFORMANCE: good	PERFORMANCE: bad	
1st ½ up cycle	37	18	
2nd ½ down cycle	25	39	
			119

V = 9.43, reject H_o since $\chi^2_{(1).95} = 3.84$

3. Intellectual (Mental) Biorhythm

Table VII

χ^2 Contingency Table for Performance Scores Versus Intellectual Biorhythm

BIORHYTHMIC CYCLE	PERFORMANCE: good	PERFORMANCE: bad	
1st ½ up cycle	36	16	
2nd ½ down cycle	27	43	
			122

V = 11.23, reject H_o since $\chi^2_{(1).95} = 3.84$

C. SECOND ANALYSIS RESULTS

The daily performance scores of each subject were further classified to take advantage of more information in the data. Four different categories were used; good performance, above average performance, below average performance and poor performance. The following tableau

illustrates the boundaries for each category. These were arbitrarily set by the experimenter.

POOR PERFORMANCE		BELOW AVERAGE		ABOVE AVERAGE		GOOD PERFORMANCE
	$-S/2$		$\bar{X}$		$+S/2$	

H_o: human performance observed is independent of biorhythmic cycle

H_1: dependency exists between human performance observed and biorhythmic cycle

$\alpha = .05$ using $\chi^2_{(3)}$ statistic

1. <u>Physical Biorhythm</u>

Table VIII

χ^2 Contingency Table for Performance Scores Versus Physical Biorhythm

BIORHYTHMIC CYCLE

PERFORMANCE	1st ½ up cycle	2nd ½ down cycle	
	20	10	good
	9	18	above average
	14	17	below average
	10	16	poor
			114

$V = 7.619$, do not reject H_o since $\chi^2_{(3).95} = 7.82$ (Note that the calculated V is close to $\chi^2_{(3).95}$ statistic)

2. <u>Sensitivity (Emotional) Biorhythm</u>

Table IX

χ^2 Contingency Table for Performance Scores Versus Sensitivity Biorhythm

BIORHYTHMIC CYCLE

PERFORMANCE	1st ½ up cycle	2nd ½ down cycle	
	19	15	good
	18	10	above average
	7	21	below average
	11	18	poor
			119

V = 10.9, reject H_o since $\chi^2_{(3).95} = 7.82$

3. <u>Intellectual (Mental) Biorhythm</u>

Table X

χ^2 Contingency Table for Performance Scores Versus Intellectual Biorhythm

BIORHYTHMIC CYCLE

PERFORMANCE	1st ½ up cycle	2nd ½ down cycle	
	19	14	good
	17	13	above average
	10	26	below average
	6	17	poor
			122

$V = 11.14$, reject H_o since $\chi^2_{(3).95} = 7.82$

The results of the second analysis, as shown in Tables VIII, IX and X, show a statistically significant dependency between human performance and biorhythmic cycles, particularly in the sensitivity and mental biorhythms.

D. CRITICALITY ANALYSIS

During the course of the experiment the subjects performed the task on days in which one or more of their biorhythms showed criticality. Measurement took place over a representitive sample of the theoretical conditions of each biorhythmic cycle. Thus no one portion of each cycle was emphasized. The experiment was performed a total of 130 days by the 4 subjects; i.e., subject 1 performed 31 days over the 15 week period, subject 2 performed 32 days, etc. The 130 particular days yielded 3 biorhythms apiece for a total of 390 data points. Criticality occurred 37 times within the 390 possibilities. Using the χ^2 test statistic, Table XI shows that there was no significant relationship between criticality and human performance.

H_o: there is no difference in the expected number of critical days in each performance category.

H_1: a difference exists in the expected number of critical days in each performance category.

$\alpha = .05$ using $\chi^2_{(3)}$ statistic

Table XI

χ^2 One Sample Criticality Table

PERFORMANCE

	good	above average	below average	poor	
Total Critical Days	9	8	10	10	
					37

V = .297, do not reject H_o since $\chi^2_{(3).95} = 7.82$

Table XI indicates that critical days were fairly evenly distributed among the four categories of performance. This lends support to the present interpretation of the theory of Biorhythms in that critical days are postulated as "unstable" days; days in which either good or bad performance can occur. Therefore, performance on critical days is not predictable in terms of performance potential for the data in this experiment.

E. REGRESSION ANALYSIS

The various biorhythmic cycles have historically been represented by sinusoidal wave patterns [Thommen, 1973]. However, it is unclear whether or not the pattern were intended to indicate like sinusoidal patterns of human performance or that the sine wave merely represented a convenient method of presentation. In other words, does the peak portion of the first half cycle represent peak performance and the low point of the second cycle represent the worst in terms of performance potential? Regression analysis was used with the data to investigate a possible relationship between the various performance scores and the common sinusoidal present-

ation of biorhythms. The following objectives and definitions apply:

(1) The objective was to obtain a regression equation in the form $Y = a + bX$ for each biorhythm using the pooled data.

Y = daily performance score

X = assumed to be of the form $\sin(2\pi d/\text{period})$, where d was the day of the biorhythmic cycle on which performance occurred.

(2) Standard linear regression techniques were employed to find estimates for a and b. The technique is summarized in Huntsberger [1973].

(3) Once the regression equations were obtained the standard "t" test was applied to test for $b = 0$. The data used in the analysis are presented in Table XIII.

(4) Regression equations obtained:

<u>Physical Biorhythm</u>: $Y = .748 + .0264X$

<u>Sensitivity Biorhythm</u>: $Y = .754 + .0072X$

<u>Mental Biorhythm</u>: $Y = .805 - .0012X$

(5) The "t" test was then applied for each equation.

H_o: $b = 0$, indicates no linear relationship

H_1: $b \neq 0$, indicates linear relationship

$\alpha = .05$

<u>Physical Biorhythm</u>: $S_b = .103$

$$t = \frac{b}{S_b} = .256, \text{ do not reject } H_o \text{ since}$$

$$t_{129(.95)} = 1.658$$

Table XII

Regression Data

BIORHYTHM

PHYSICAL					SENSITIVITY					MENTAL				
ΣX	ΣX^2	ΣY	ΣY^2	ΣXY	ΣX	ΣX^2	ΣY	ΣY^2	ΣXY	ΣX	ΣX^2	ΣY	ΣY^2	ΣXY
-3.467	53.998	97.177	73.199	-1.166	.244	62.693	97.177	73.199	.635	-2.6	62.264	97.177	73.199	-2.018

Sensitivity Biorhythm: $S_b = .094$

$t = .075$, do not reject H_o since

$t_{129(.95)} = 1.658$

Mental Biorhythm: $S_b = .094$

$t = -.0125$, do not reject H_o since

$t_{129(.95)} = 1.658$

The conclusion is that no statistically significant linear relationship which exists for X and Y variables when the X variable is of sinusiodal form for each of the three biorhythms.

IV. DISCUSSION

In the First Analysis (Tables VI and VII), a significant dependency between human performance and the sensitivity and intellectural biorhythms was observed at the .05 level. However, the dependency between the physical biorhythm and human performance, as shown in Table V, was not significant at the .05 level. The First Analysis considered performance only in two distinct categories: good performance and bad performance. It was felt that more information could be gained from the data if the categories of performance were extended to four. Hence, the Second Analysis reflected four distinct categories of human performance: good, above average, below average and poor.

The results of the Second Analysis, as indicated in Table IX, showed statistically significant dependency between human performance and the sensitivity biorhythm at the .05 level. Similar dependencies have been shown between this biorhythm and industrial accidents. [Gionnotti, 1974] The sensitivity biorhythm is behaviorally characterized by nerves, feelings, intuition, creative ability and emotion [Thommen, 1973]. The performance in the task employed in the present experiment can be affected by all of these factors. Since the colors appeared every 1½ seconds, the concentration of the subject was necessary to insure a greater number of correct responses. If the subject felt nervous or emotionally drained his performance at the RATER task might well be affected adversely. Conversely if the subject felt relatively good emotionally his performance might well be better than normal. The results of this study confirmed a statistically significant relationship between nature of performance and phase of the sensitivity biorhythm. The results of the Second Analysis,

as indicated in Table X, showed a statistically significant dependency between human performance and the intellectual biorhythm. The intellectual biorhythm is behaviorally characterized by memory, mental alertness, reaction, agility and reasoning power [Thommen, 1973]. When the level of these factors is low, below average performance would be expected in the RATER task; especially since the task required good mental alertness and reaction.

Thus the results showing dependency between the human performance and the sensitivity and intellectual biorhythms are not surprising when the task is examined in the light of the characteristics of these biorhythms.

The results of the second analysis of the performance scores versus the physical biorhythm (see Table VIII) showed no significant dependency between the two variables at the .05 level. However two observations must be made concerning these results.

First, the χ^2 test statistic showed that there was a significant dependency between the physical biorhythm and human performance at the .1 level.

Secondly, the difference in significance levels can be accounted for, in part, by the nature of the tasks employed. The RATER task is not inherently physical in nature. Although the cognitive and purely physical processes of human performance are difficult to separate, other more directly physical task could be designed to investigate the physical biorhythm.

The lack of historical data supporting the sinusoidal representation of biorhythmic periodicity led to the regression analysis employed. Apparently the sine wave was chosen to represent only the idea of "up" and "down" cycles. The objective of the regression analysis was to

investigate if any relationship could be established between the daily performance scores and the sinusoidal nature of the biorhythmic cycles. Put another way, could the human performance observed in this experiment be characterized as sinusoidal in nature? The results of the "t" test showed that there was no linear relationship between the scores and the sinusoidal representations of the three biorhythmic cycles. These results do not imply that no cyclic phenomena is taking place. Rather they indicate simply that the performance of the subjects does not correspond to sinusoidal periodicity.

The criticality analysis in Table XI showed that performance on critical days was distributed fairly evenly. Attempts to characterize critical days as "down" days exclusively do not coincide with the present theory of Biorhythms. A critical day is considered as an unstable day and is "critical" in the sense that a particular biorhythmic cycle is at the point of crossing the horizontal axis. The potential for good as well as bad performance exists on a critical day. Unfortunately critical days have been mainly considered in relation to incidents of bad performance, such as aircraft accidents attributable to pilot error. Good performance is usually portrayed by investigators in relation to "up" cycle days. An example would be the winning performance of pro quarterback Joe Namath in the 1969 Super Bowl [Thommen, 1973]. His biorhythms were in the "up" cycle on that day. The confusion arises because no one seems to show that good human performance can also occur on critical days. The results of the present experiment showed that above average and good performance did occur on critical days.

The present experiment was one of the first long term efforts to monitor human performance and biorhythms in a laboratory situation.

Further research is suggested with a longer time span and a larger subject sample. Performance over a longer time span would tend to randomize out errors resulting from emotional instability of the subject. A possible problem in task design would be that the task employed might become boring to the subjects, thus introducing other kinds of bias.

Several conceptual questions remain as topics to consider in future research. For example the present theory of Biorhythms postulates that biorhythms originate at birth. The question might well be asked: why do they not originate at conception? Of course the question of exactly when life does begin must be considered.

The state of the art, scientifically, in the use of biorhythms is elementary. Several industrial organizations are reportedly allocating considerable expenditures to study the phenomenon of biorhythms in work scheduling. These companies have reported significant decreases in industrial accident rates. The analogy to the military is obvious. With loss-work accidents costing millions of dollars per year, any improvements would be noteworthy both costwise and in a human factors sense.

The view that biorhythms application will accurately predict a person's future behavior seems erroneous at this stage. Rather, biorhythms can serve to explain a part of the immensely complex area of human behavior. Even if the causes of biorhythmic periodicity are not fully understood, the study of it's effects on humans is a most worthwhile and scientific endeavor.

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